Fermilab

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A PRELIMINARY DESIGN FOR A 20 TeV COLLIDER IN A DEEP TUNNEL AT FERMILAB

Fermi/SSC Study Group

The Reference Design Study for a 20 TeV Collider demonstrated the technical and cost feasibility of a 20 TeV superconducting collider facility. Based on magnets of 3T, 5T, and 6.5T the Main Ring of the Collider would have a circumference of 164 km, 113 km, or 90 km. There would be six collision regions, of which four would be developed initially. The 5T and 6.5T rings would have twelve major refrigeration stations, while the 3T design would have 24 major refrigeration stations.

At the CERN Laboratory in Switzerland the 450 GeV, 6 km circumference, SPS accelerator has operated successfully in a deep tunnel under a relatively densely populated area for about ten years, and the same deep tunnel model is adopted for the 27 km circumference LEP accelerator now under construction. An investigation has been made of the feasibility of siting the SSC in a deep tunnel under Fermilab. This would have the advantage of making use of the existing Tevatron as injector, resulting in a cost savings for the injector and campus facilities of the order of $500M, while expediting the construction of the accelerator by requiring construction of only the Main Ring. It would also make use of the existing experienced staff. As at CERN advantages of a deep tunnel are that there is very little perturbation of the surface, requiring only minimal land acquisition, while at the same time radiation exposure to the general public is essentially eliminated by the depth of overburden.

I. Population Considerations

The population density in the vicinity of Fermilab at the time of the 1980 census is shown in Fig. 1, which illustrates the relatively low density of population in the area to the west of the Fermilab site. Figure 2 illustrates the population distribution relative to a possible 20 TeV ring. The dark areas are incorporated areas. The fortuitous low density north-south corridor at the eastern edge of the Fermilab site makes it possible for the 20 TeV ring to avoid essentially all concentrations of population. Figure 3, a plot of wells drilled to an elevation of 400' illustrates the same avoidance of concentrations of population.

II. Geotechnical Considerations

The geological formations underlying the region around Fermilab consist largely of relatively undisturbed dolomite. In recent years over 40 miles of tunnel have been excavated in these formations in connection with the Chicago Tunnel and Reservoir plan (TARP) so considerable data and experience exist, with respect to both the geology and the techniques and costs of tunneling in the dolomite. In addition, well data have been collected by the Illinois Geological Survey, which are being supplemented by specific borings made along the proposed ring. (Fig. 2, numbered points.) A draft Geologic Report for the proposed SSC has been prepared by the Illinois Geological Survey (J.P.Kempton, et al., July 1984). The report summarizes the geological information available for the region.

Overburden

The general topography on the area of the proposed ring is indicated in Fig. 4. The overburden is comprised largely of glacial drift. The glacial drift consists generally of three types of materials: till; outwash; and lacustrine deposits.

The till generally consists of a heterogeneous mixture of particles of all sizes. Till ranges from very compact to loose and friable. The heterogeneity of till results from direct deposition by glacial ice without any significant sorting action by water.

The outwash consists of material deposited by glacial meltwaters and generally consists of coarser sands and gravels.

The lacustrine deposits consist chiefly of laminated silt and clay which were deposited in glacial lakes.

Bedrock

The bedrock topography is indicated on Fig. 5 from the referenced report by the Illinois Geological Survey. This map has been compiled from records of water wells and test borings.

Stratigraphically, the bedrock consists of paleozoic sediments deposited in a shallow sea. The stratigraphic units which will be encountered in the proposed tunnel include formations of the Silurian and Ordovician Systems.

The Silurian units which will be encountered, are comprised of dolomites of the Kankakee and Elwood formations. These dolomites are dense, fine grained rocks.

The units of the Ordovician System which will be encountered consist of the Maquoketa, Galena, and Platteville Groups. The Maquoketa Group is comprised of: the Brainard formation, a dolomite shale; the Fort Atkinson formation, a dolomite; and the Scales formation, a dolomitic shale. Units which will be encountered in the Galena Group consist of dolomites of the Wise Lake, Dunleith, and Guttenberg Formations. The Platteville Group consists of hard, fine grained dolomites.

Structurally, the bedrock units are essentially undisturbed in the project area. The general dip of the units is to the east at approximately 10' to the mile. The Sandwich fault zone occurs to the southwest of the project area approximately 3 miles from the proposed tunnel alignment. No movement has occurred along the fault zone during historical times, nor has any evidence of movement been found in the glacial drift of this region. Regional geologic studies indicate that the last time faulting occurred was about 250 million years ago.

Groundwater

Groundwater sources for small production wells (10 to 300 gpm) are generally in the glacial drift, sometimes bottoming in the top of rock. These wells may be up to 300' in depth. Groundwater sources for high production wells (over 500 gpm) are generally extended to depths of over 1000' and extend into the Galena-Platteville or underlying sandstones. Deep wells are isolated from the overlying units by means of grouted casing.

III. Ring Elevation

The most suitable formation in which to site the accelerator tunnel is the dolomite of the Galena-Platteville layer. In Fig. 6, the extent of undisturbed Galena-Platteville with a protective rock overlay is seen to encompass essentially the whole area of the proposed ring. The initial proposed siting of the ring in this formation is illustrated in cross-section in Fig. 7, and in perspective in Fig. 8. A typical boring along the ring location is given in Fig. 9.

IV. Ring and Lattice Characteristics

The presence of Fermilab with its large acreage makes it attractive to adapt the ring somewhat from the Reference Design. In particular, clustering of the experimental areas permits half of them to be located on the site, Fig. 10. Clustering obviates the need to acquire large tracts of new land for the associated support facilities. With the exception of the remaining cluster of Interaction Regions on the west side of the ring, the only equipment along the periphery are the 12 refrigerator stations located at 5.3 mile intervals, Fig. 11.

Studies of the relative costs of surface and tunnel excavations for Interaction Regions indicate that, for the large spans involved, the costs are essentially invariant when the costs of bringing the ring to the surface are folded into the surface costs. It may be useful then, on the east side of the ring at the Fermilab site, to bend the accelerator out of the plane and bring the ring closer to the surface for the large IR's on site. This allows larger spans for the IR's, and also considerably reduces the length and steepness of the injection adits. Soft-tunneling techniques would be used from bedrock to the edge of the Fermilab site.

For cryogenic reasons the large cold box and helium dewar for each refrigerator must be located at the tunnel level. In a deep tunnel configuration the compressors and power supplies could also be located at this level as shown in Fig. 12. Experience on the TARP project indicates that such spans are easily accommodated in the dolomite and the excavation costs are competitive with providing equal space at the surface and running piping and electrical connections from the surface.

V. Tunnel Cross-Section Considerations

Considerable data exist from the TARP project on tunnels with cross-sections similar to the projected SSC tunnel. The experience on TARP is that in undisturbed dolomite no lining is required. The bored tunnel diameter can then be the nominal finished cross-section of the RDS tunnel, which is 9'.

A further advantage of the unlined tunnel is the possibility of squaring the base to gain width at the bottom, as is done in mining. Fermilab experience in installing and operating both the conventional Main Ring and the Tevatron indicates that a 9' diameter tunnel is adequate, provided the floor is wide enough to allow something like 6' of aisle for vehicles and personnel.

VI. Power Distribution

Up to 200 MW of electrical power is presumed for the Reference Design. This must be derived from a firm grid, and preferably have several feed points to ensure continuity of essential operations in case of failure of one transmission line source. Fermilab is presently fed by a 345 kV line from a power corridor on the east side of the site. Two additional 345 kV lines and two 138 kV lines are contained in the same corridor. One 345 kV line and one 138 kV line traverse the site across the diameter from east to west. Two 345 kV lines and one 765 kV line intercept the ring at the south extremity. These are indicated in Fig. 13. Total Commonwealth Edison system capacity is 17,587 MW. Each of the 345 kV lines has a capacity greater than 500 MW. A large fraction of this power is from nuclear plants which is not subject to large fluctuations in the fuel adjustment charge.

Primary power from main feed points could be distributed in the tunnel.

VII. Availability of Cryogens

A critical factor in operation of a superconducting accelerator, which is not encountered in the operation of conventional accelerators, is the ready availability of large quantities of cryogens - helium and nitrogen. Fermilab is located in the Chicago area, which has a heavy concentration of industrial users of cryogenic gases, and so an excellent supply base. Both helium and nitrogen are readily available in large quantities on short notice to maintain operation of the accelerator complex. (Fig. 14)

Other siting factors not specific to the SSC, like manpower, human amenities, water, etc., have been met in the original choice of the Fermilab site, The excellent road network in the vicinity is shown in Fig. 15.

REFERENCES

1. Preliminary Draft Report, "The 20 TeV Accelerator in Illinois: A Preliminary Geological Feasibility Study," J.P.Kempton, et al., Illinois State Geological Survey, Champaign, IL 61820, April 1984.

2. Draft Report: "Studies for an Accelerator Tunnel in Rock at Fermilab," Harza Engineering Company, Chicago, IL, December 1984.

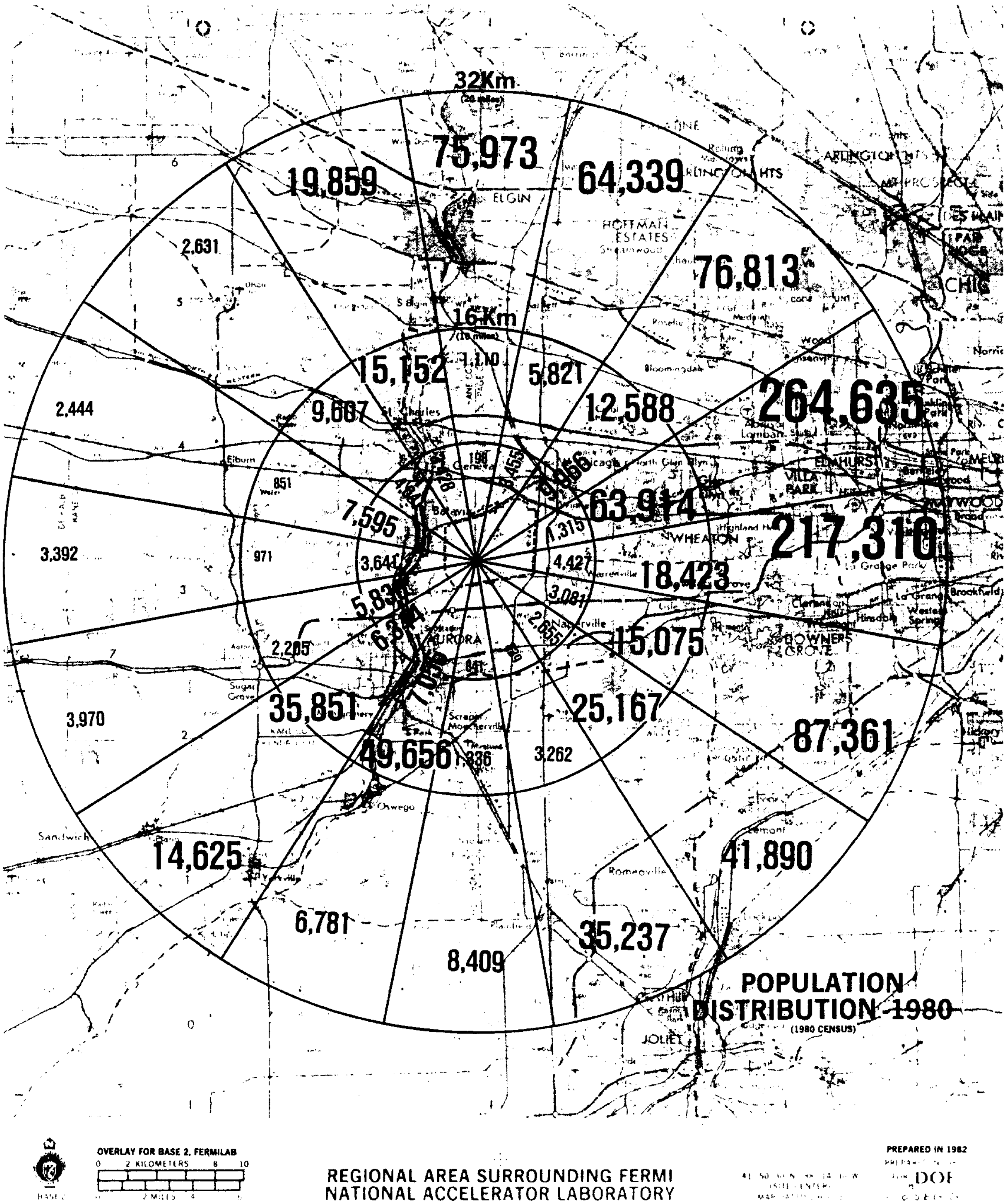


Figure 1. Population Density in Fermilab Area

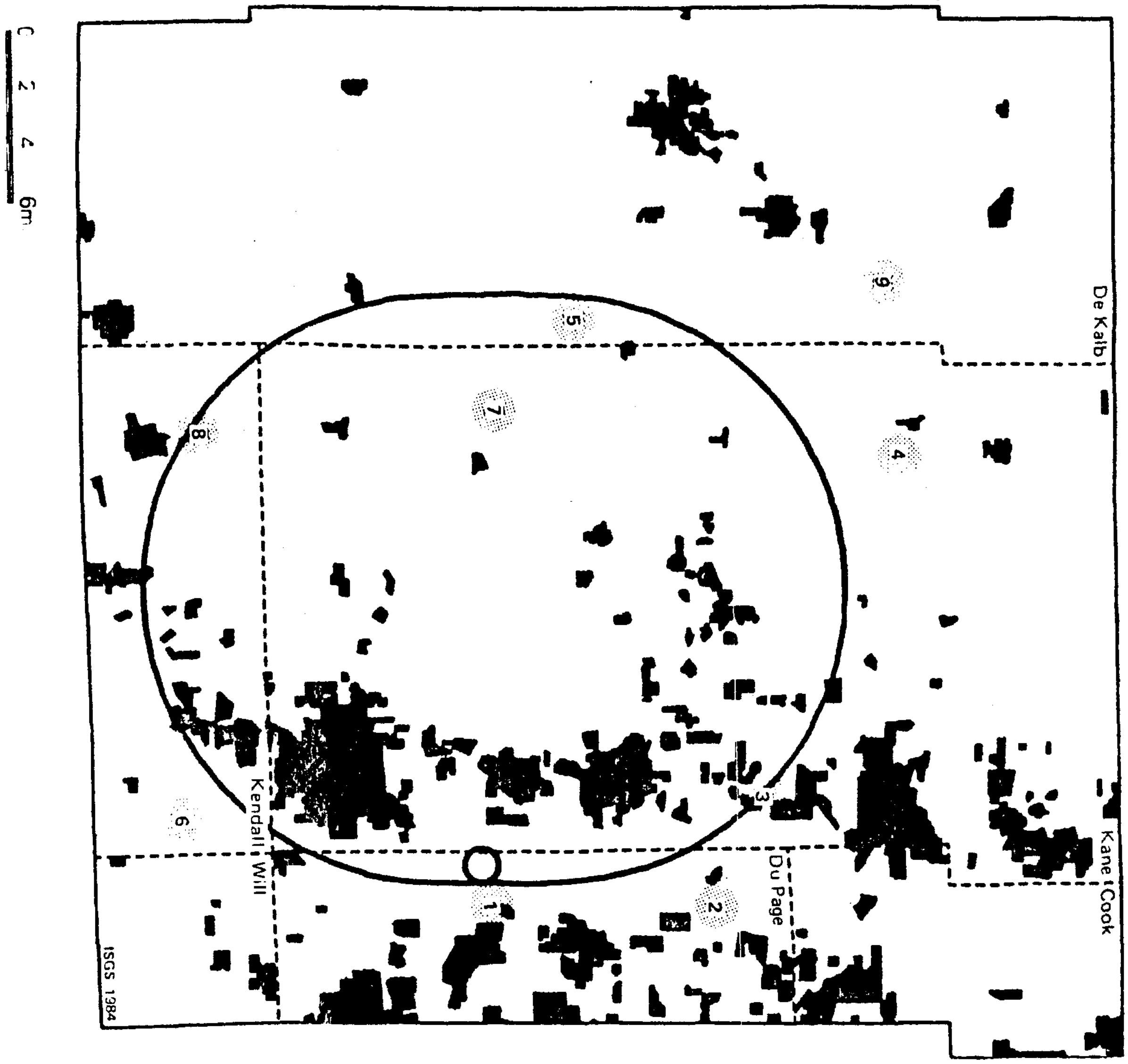


Figure 2. Population Distribution
(ISGS - Preliminary)

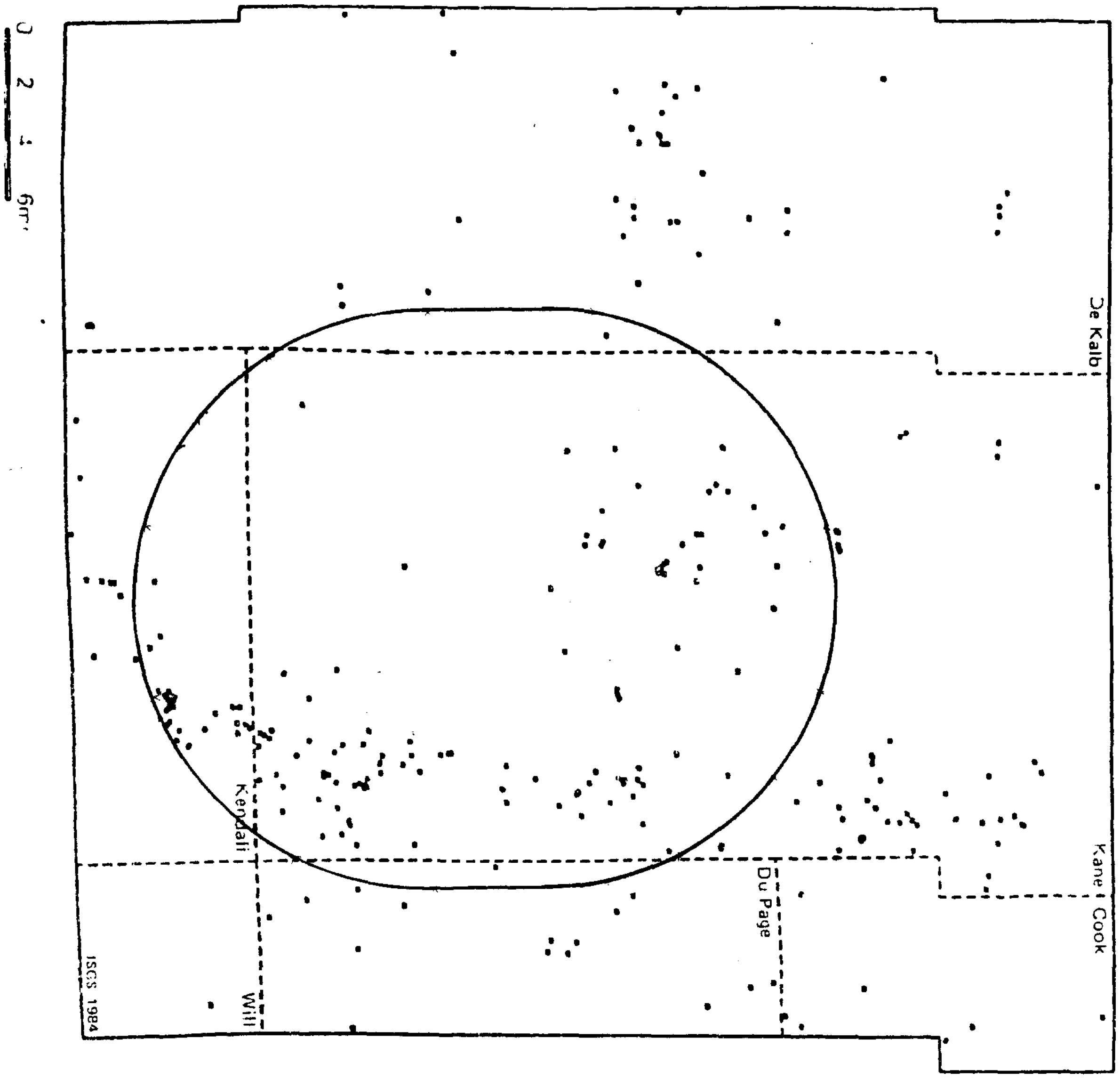


Figure 3. Wells drilled to elevation 400'
(ISGS preliminary)

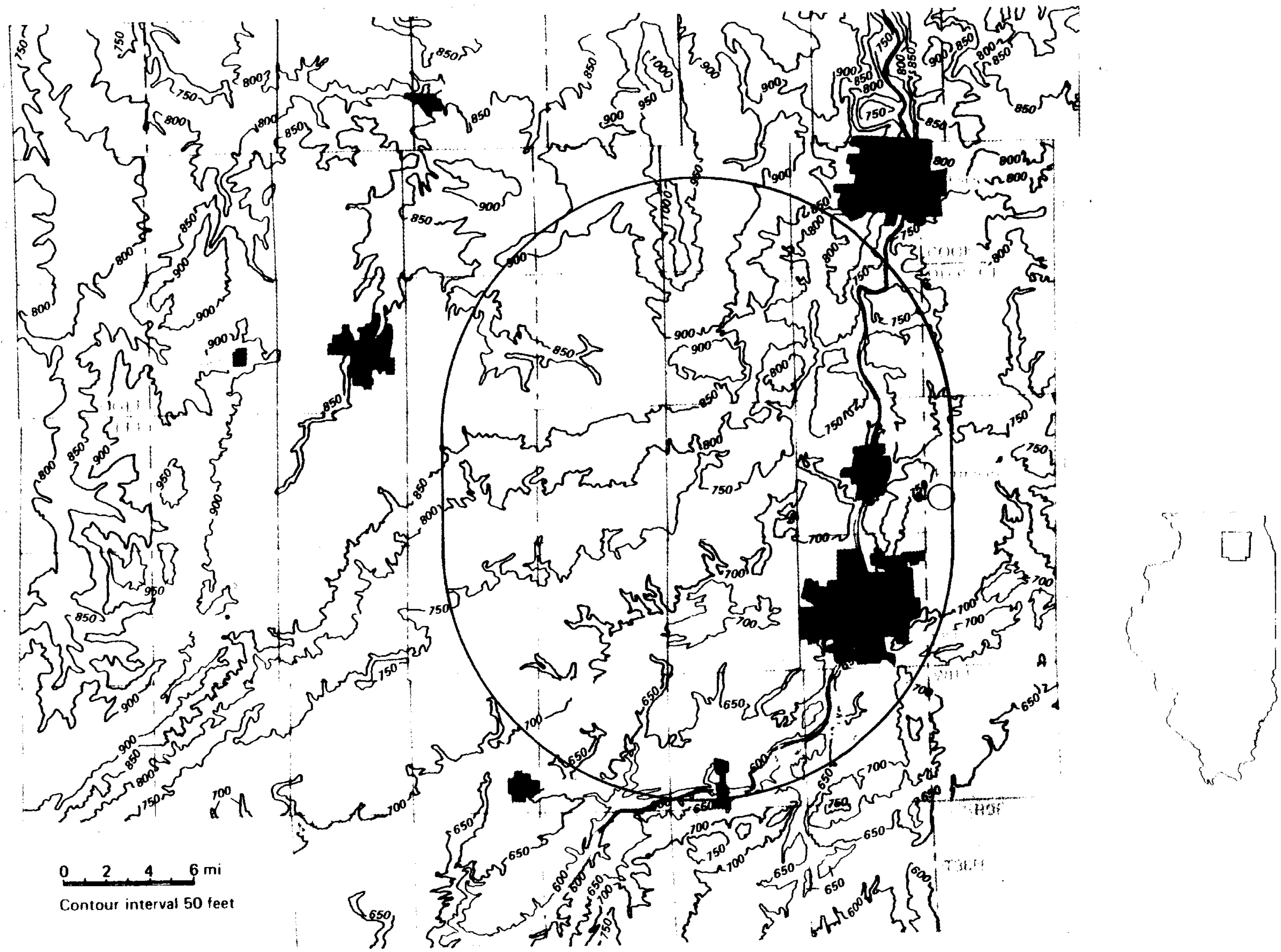


Figure 4. Area of study showing generalized topography.
(ISGS - Preliminary)

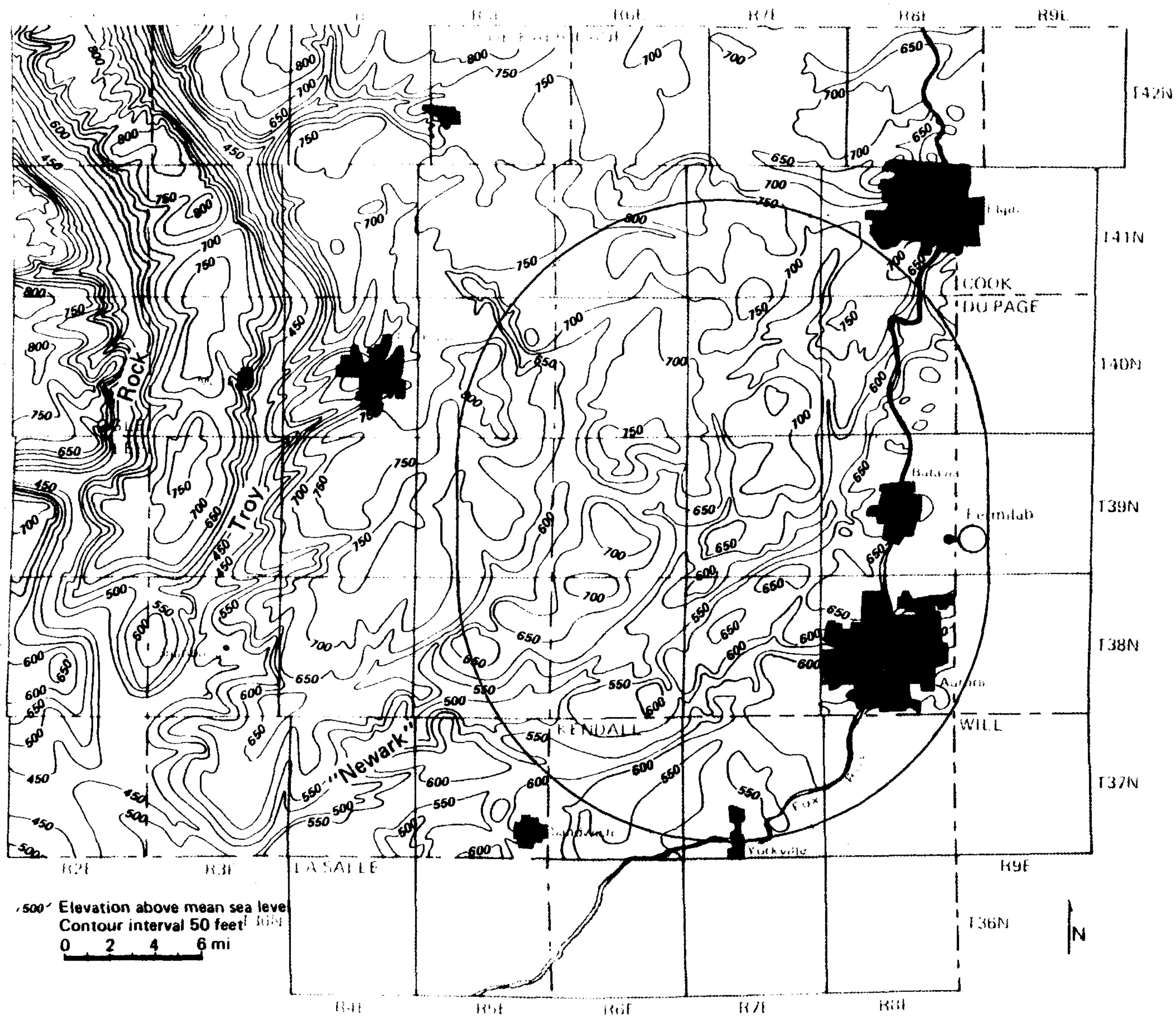


Figure 5. Bedrock topography of study area (after Wickham, 1979). (ISGS - Preliminary)

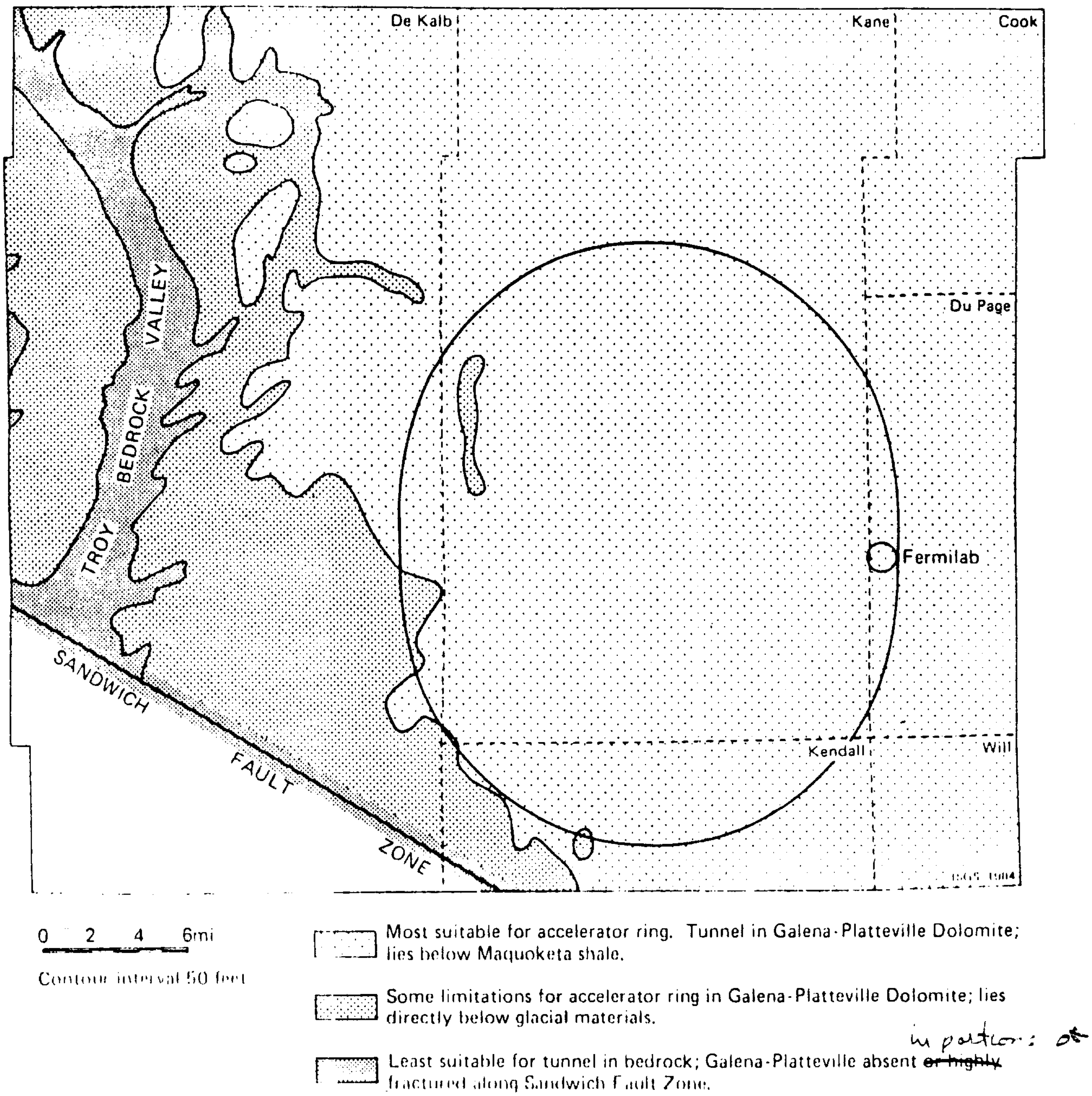


Figure 6. Bedrock Topology
(ISGS - Preliminary)

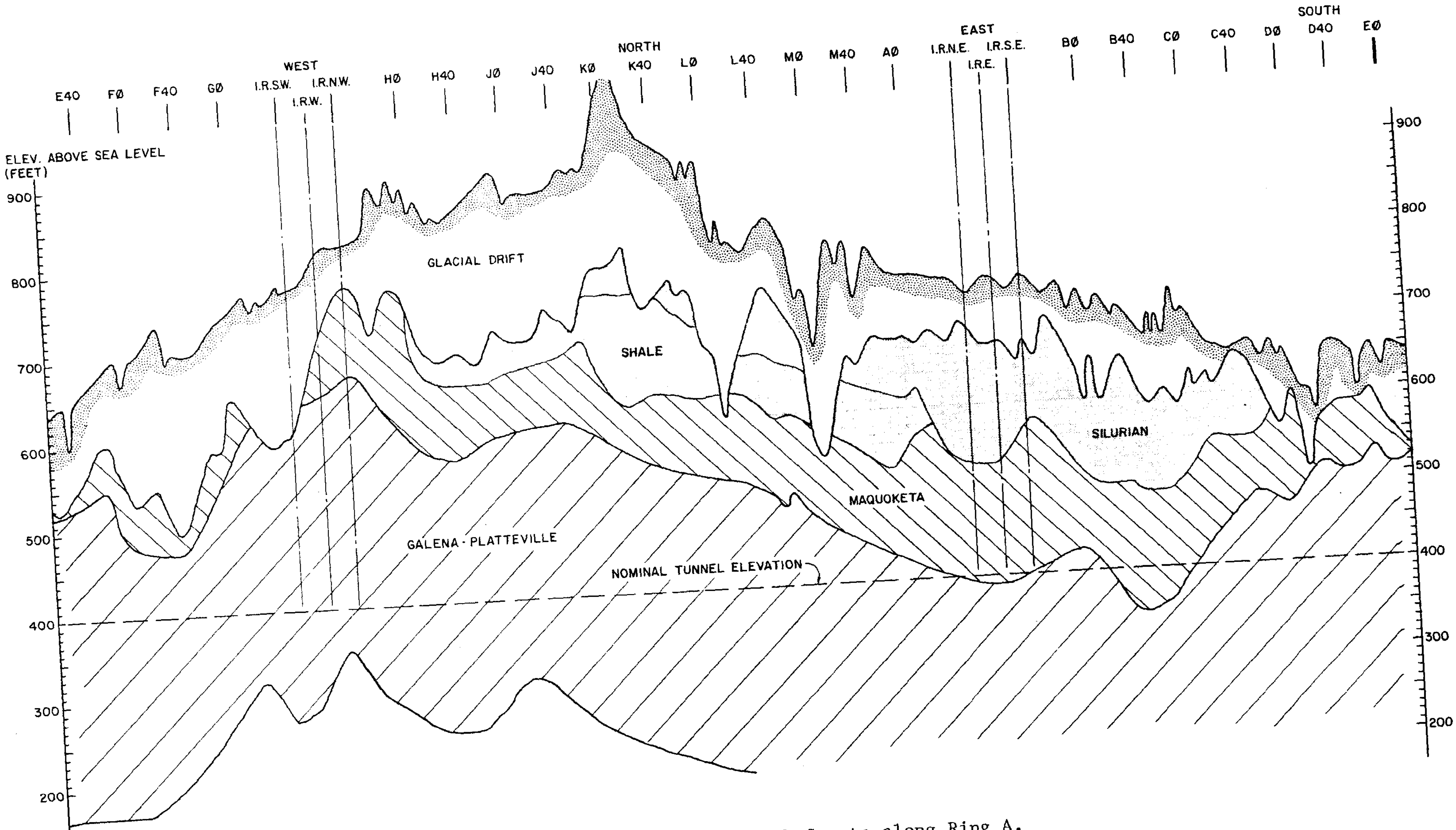


Figure 7. Bedrock Strata along Ring A.
(ISGS - Preliminary)

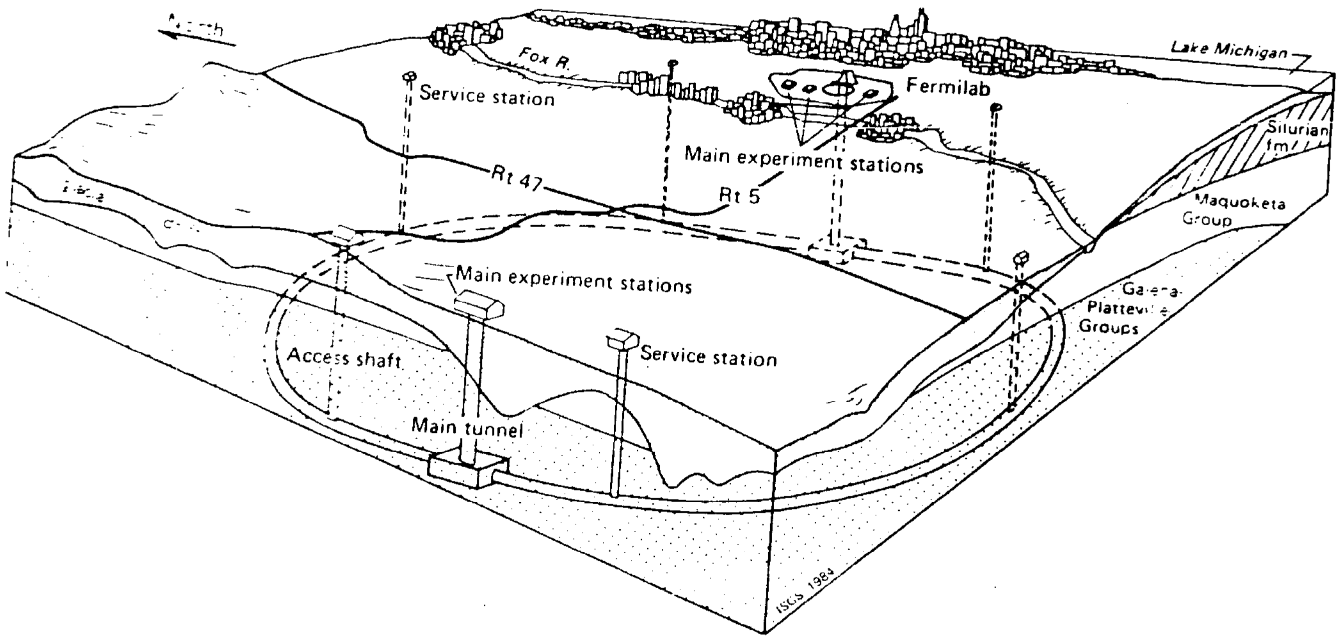
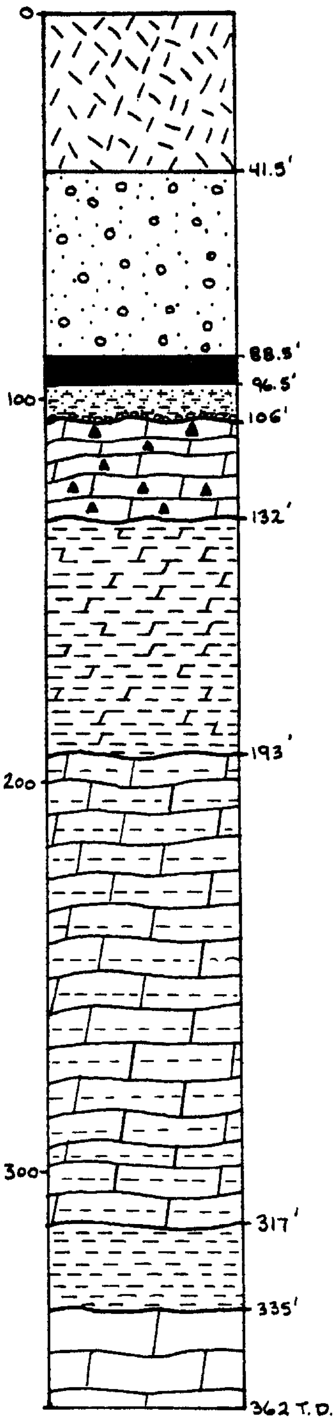


Figure 8. Conceptual Siting of SSC at Fermilab
(ISGS - Preliminary)

TEST HOLE

F-4



QUATERNARY SYSTEM

PLEISTOCENE SERIES

WEDRON FORMATION

TISKILWA MEMBER - reddish-brown loamy till (0'-41.5'); interbedded sandy gravel, gravelly silt, loamy till (41.5'-88.5')

ROBEIN SILT - black, organic-rich, silty loam (88.5'-96.5')

GLASFORD FORMATION

BELVIDERE MEMBER (?) - olive gray silt, silty clay and gravel (96.5'-106')

SILURIAN SYSTEM

ELWOOD FORMATION

Dolomite - light-olive-gray to light greenish-gray fine grained, very cherty, wavy beds separated by thin greenish-gray shale partin (106'-132')

ORDOVICIAN SYSTEM

MAQUOKETA GROUP

BRAINARD FORMATION

Shale - greenish-gray, silty, dolomitic, soft; minor dolomite beds - light-olive-gray, fine-grained in irregular nodular beds fossiliferous. (132'-193')

FORT ATKINSON FORMATION

Dolomite - light-olive-gray, mottled and speckled dark gray, fine to coarse grained, argillaceous, very fossiliferous (brachiopods and bryozoans), vuggy; in wavy beds separated by thin olive-gray shale partings. (193'-317')

SCALES FORMATION

Shale - olive-gray, dolomitic, fossiliferous, laminated (317'-335')

GALENA GROUP

WISE LAKE FORMATION

Dolomite - pale yellow brown, fine to medium grained, vuggy, pyritic; in wavy beds separated by olive-gray shaly partings. (335'-362')

Figure 9 Test Hole F-4
(ISGS - Preliminary)

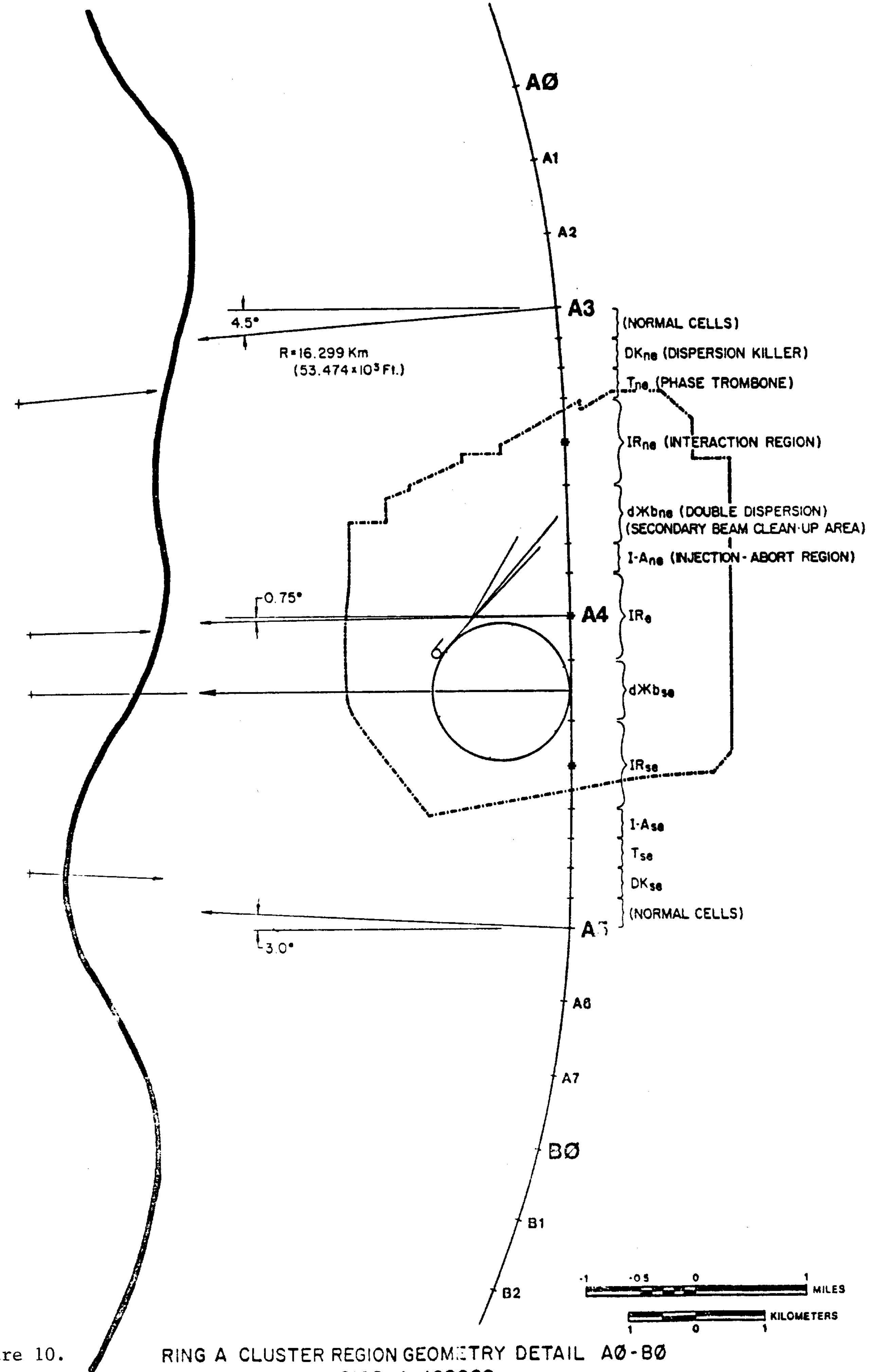


Figure 10. RING A CLUSTER REGION GEOMETRY DETAIL AØ-BØ

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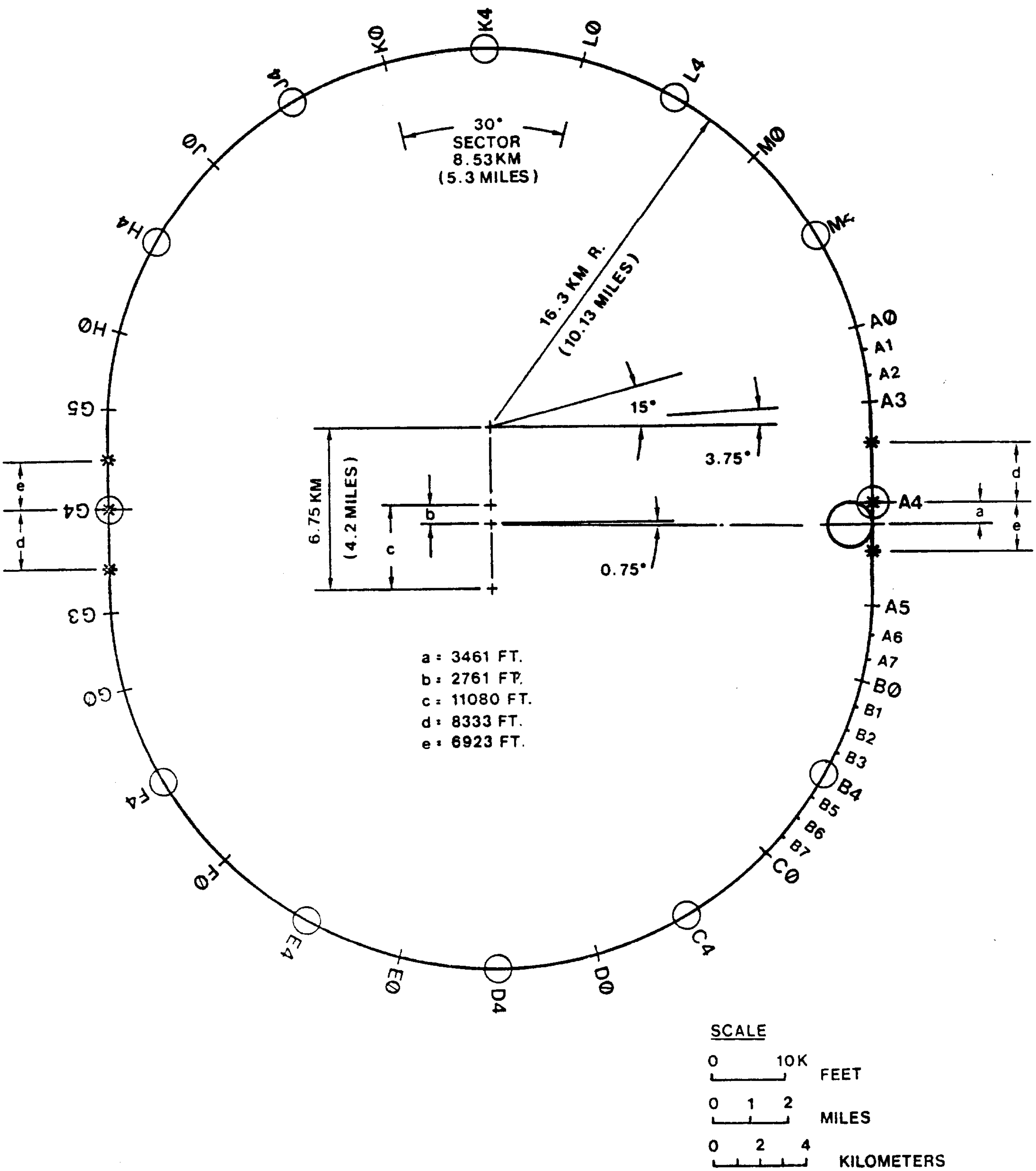
Figure 11. Lattice with Clustered IR's.



RING 'A' GEOMETRY
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SSC

MAJOR SERVICE AREA

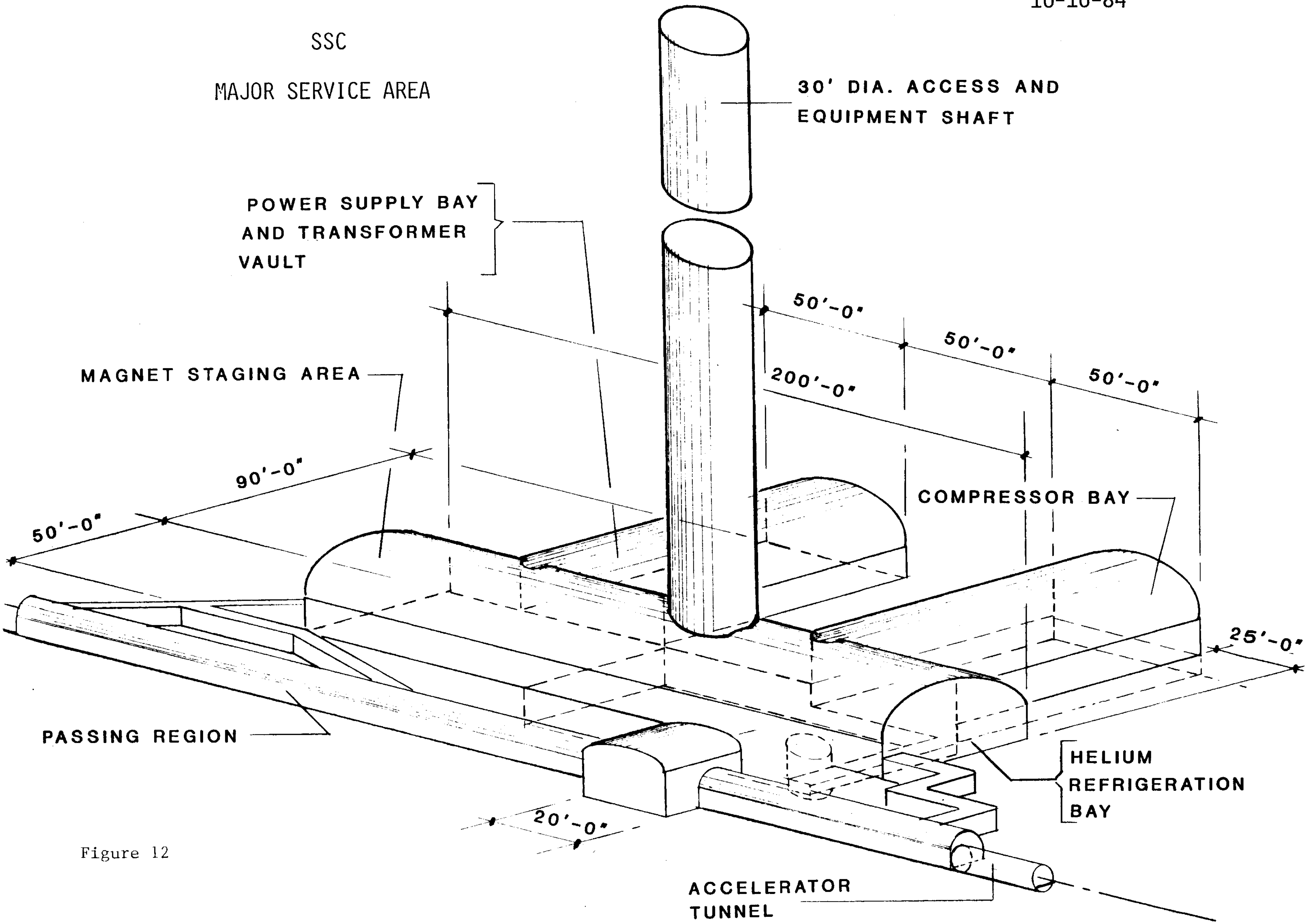

Figure 12

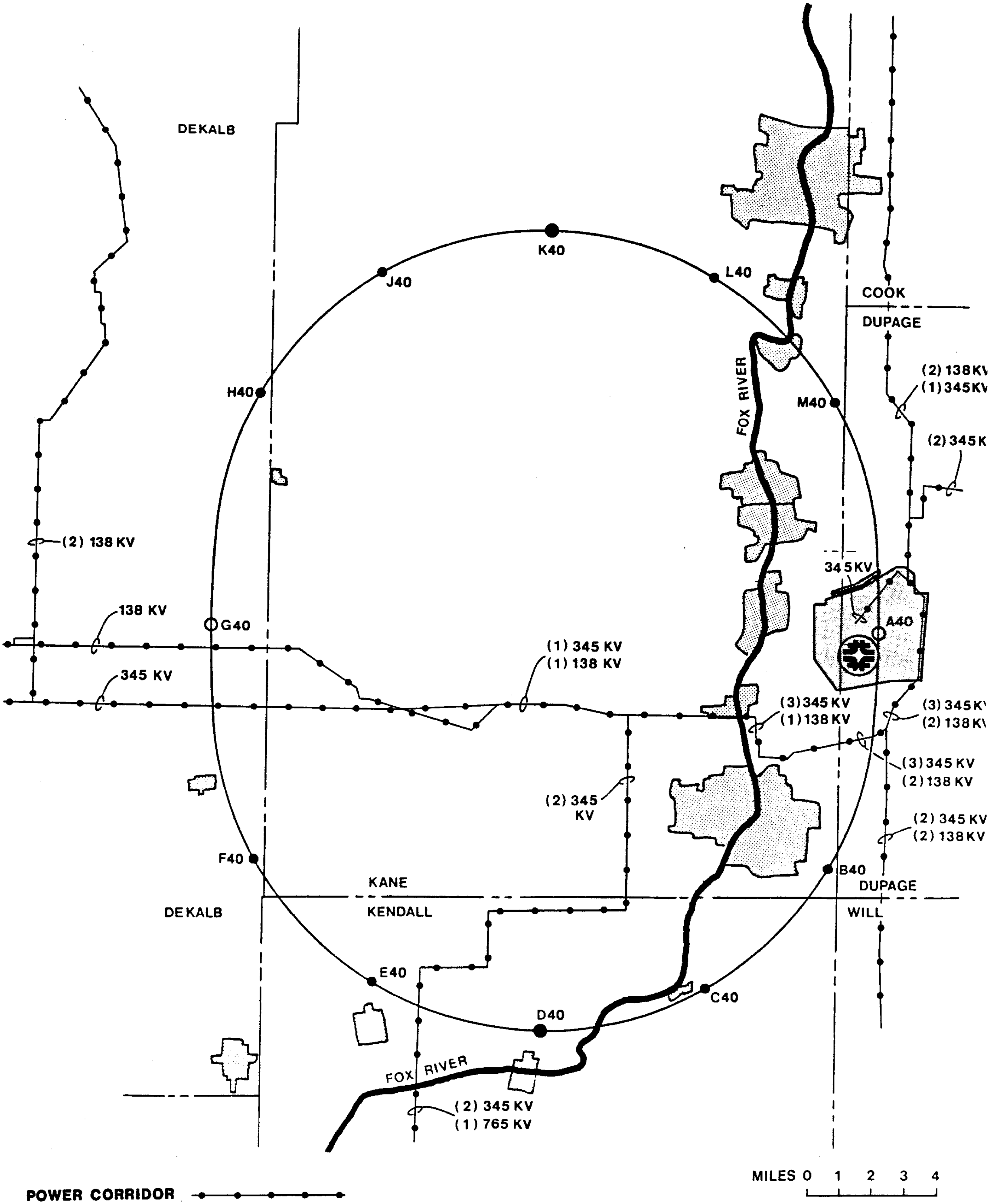

Figure 13

HIGH VOLTAGE DISTRIBUTION IN SSC AREA

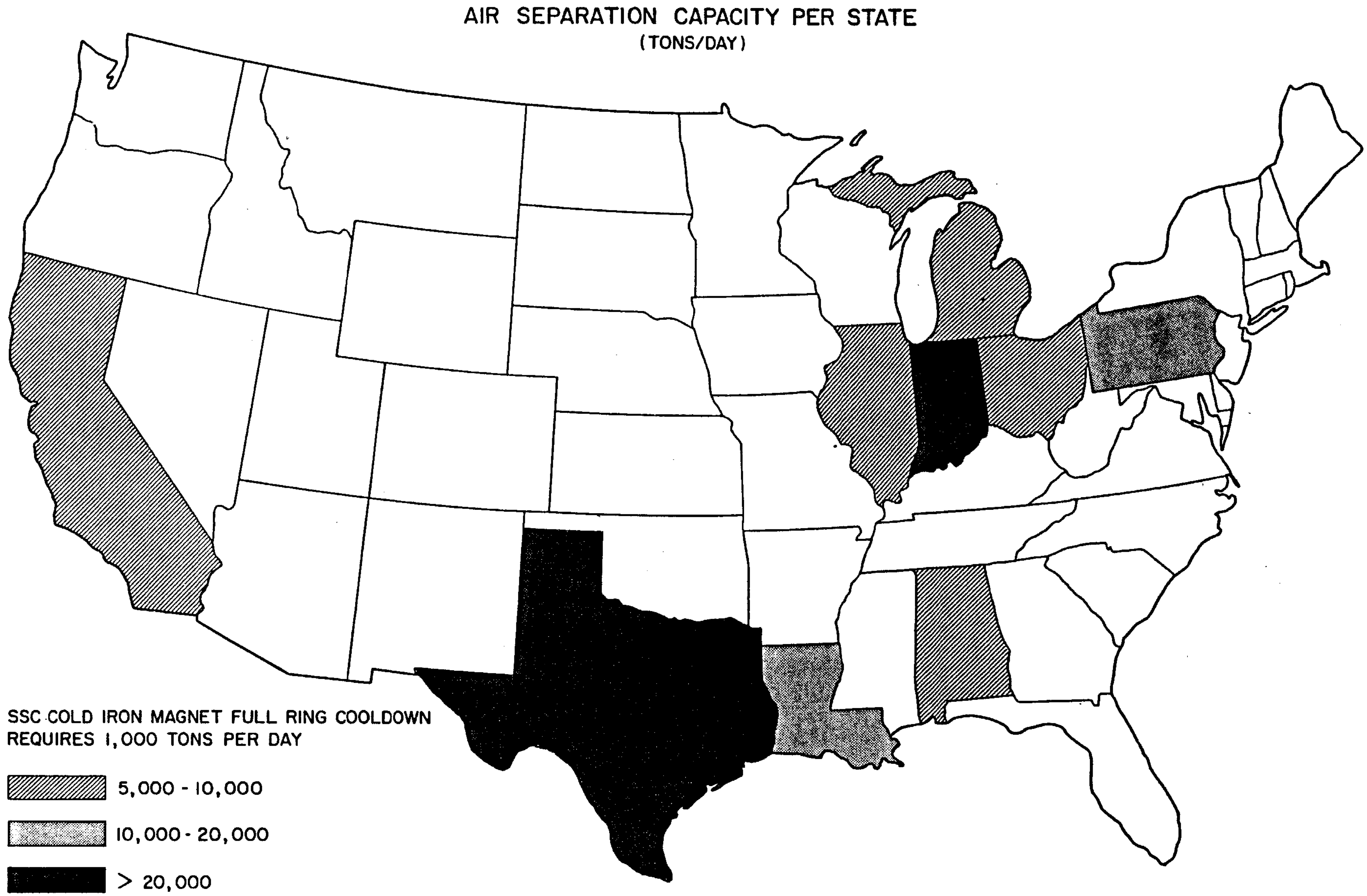
AIR SEPARATION CAPACITY PER STATE
(TONS/DAY)
SSC COLD IRON MAGNET FULL RING COOLDOWN
REQUIRES 1,000 TONS PER DAY
5,000 - 10,000
10,000 - 20,000
> 20,000

Figure 14

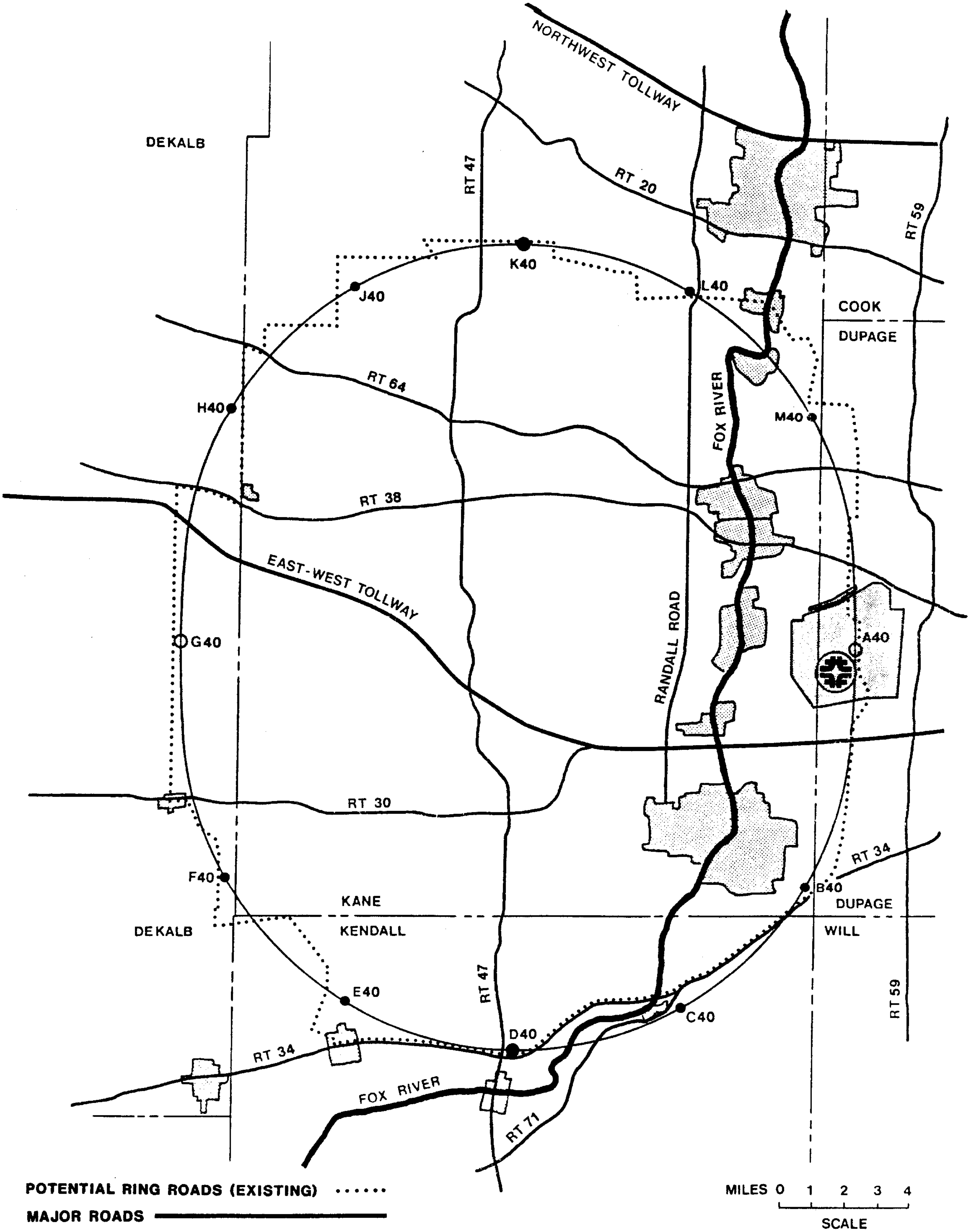

Figure 15

ROAD SYSTEM IN SSC SITE AREA